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Modeling Alternative Policies for GHG Mitigation from Forestry and Agriculture

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Modeling Alternative Policies for GHG Mitigation from Forestry and Agriculture

Abstract

A key consideration for development of energy and climate policy affecting the forestry and agricultural sectors is that the selection of specific mechanisms implemented to achieve bioenergy production and/or greenhouse gas (GHG) mitigation targets may have substantial effects on landowner incentives to adopt alternative practices. For instance, the prices of allowances and offsets are expected to diverge under some policies being considered where there is a binding cap on the quantity of offsets from the agricultural and forest sectors. In addition, provisions that limit or exclude specific practices from receiving carbon payments will affect the quantity and cost of GHG mitigation opportunities available. In this study, the recently updated Forest and Agriculture Sector Optimization Model with GHGs (FASOMGHG) was used to estimate GHG mitigation potential for private land in the contiguous U.S. under a variety of GHG price policies. Model scenarios suggest that U.S. forestry and agriculture could provide mitigation of 200 – 1000 megatons carbon dioxide equivalent per year (Mt CO_2e/year) at carbon prices of \$15 to \$50/tCO_2e. Binding limits on offsets have increasingly large effects on both the total magnitude and distribution of GHG mitigation across options over time. In addition, discounting or excluding payments for forest sinks can reduce annualized land-based mitigation potential 37-90 percent relative to the full eligibility scenario whereas discounting or excluding agricultural practices reduces mitigation potential by less than 10 percent.

Keywords: Climate policy, energy policy, FASOMGHG, GHG mitigation

JEL Classification: C61, Q42, Q54

Introduction

Forestry and agricultural activities are widely recognized as potential low-cost greenhouse gas (GHG) mitigation options, particularly in the near term while alternative energy technologies are in the development stage. Changes in forestry and agriculture practices can reduce and avoid the atmospheric buildup of the three most prevalent GHGs directly emitted by human actions: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The removal of atmospheric CO_2 through sequestration in carbon "sinks" is a mitigation option in forestry and agriculture that has received particular attention in recent United States climate change legislative proposals as well as policies introduced by the international community. However, the level of GHG mitigation available from the forestry and agriculture sectors is dynamic and can differ substantially as a result of market phenomena or policy actions that influence land use.

An important but frequently overlooked issue in developing guidelines for the inclusion of forestry and agriculture is the implications of selecting specific mechanisms through which mitigation is achieved. For instance, whether these sectors are allocated allowances under a cap-and-trade system or provide mitigation through an offset market will potentially have significant effects on mitigation, land use, commodity production, and prices. This may be particularly important in the case of bioenergy, where the use of forest and agricultural feedstocks would reduce emissions from regulated sectors and would reduce the consuming entities need for allowances rather than serve as an offset. In addition, energy prices as well as separate bioenergy policies (e.g., renewable portfolio standards (RPS) or renewable fuel standards), have important interactions with policies focused on GHG mitigation for these sectors.

Because policy provisions are likely to cause the market prices for allowances and offsets to increasingly diverge over time, the design of bioenergy and GHG mitigation policy has important implications for the mix and volume of mitigation options adopted. In addition, provisions that limit or exclude specific practices will affect the quantity and cost of mitigation opportunities available. In this study, we analyze the impacts of alternative GHG mitigation policy designs and study the effects of competing policies and developments using the Forest and Agricultural Sector Optimization Model with Greenhouse Gases (FASOMGHG) model. Our results highlight the importance of energy and climate policy design for land use, commodity prices, and GHG mitigation.

Background

U.S. forests and agricultural lands currently provide a large net carbon sink estimated at 940 teragrams[1] (Tg) of CO_2 equivalent (CO_2e) per year (EPA, 2010a), enough to offset roughly 13.5 percent of U.S. GHG emissions. After accounting for agricultural CO_2 and non-CO_2 emissions (CH_4 and N_2O), the forest and agriculture sectors still offset about 6.9 percent of total U.S. GHG emissions (EPA, 2010a). The forestry and agricultural sectors can provide GHG mitigation above the baseline sink through reduced emissions (e.g., changes in soil nutrient management, manure management), increased sequestration (e.g., afforestation, forest management, reduced tillage), or by providing feedstocks that substitute for fossil fuels (bioenergy production) as discussed in McCarl and Schneider (2001). These contributions are not typically included under the national GHG cap in current legislative initiatives, but may provide offsets that can help covered emitters in meeting the cap.

Expanding mitigation in the forestry and agricultural sectors can potentially reduce the cost of compliance[2], but the level is dynamic and can change considerably due to natural events, market conditions or changes in policies that impact land use. Energy and climate policy will play key roles in shaping the future of these sectors. In previous analyses of the

[1] One teragram equals one million metric tons.
[2] For instance, EPA analyses of the American Power Act of 2010 (EPA, 2010b) found that the use of offsets can significantly reduce the cost of economy-wide climate policy. A scenario with unlimited domestic and international offsets was found to reduce the marginal cost of GHG reductions by 34 to 118 percent relative to the core policy scenario.

quantity of offsets potentially available from the forestry and agricultural sectors, it has often been assumed that all available mitigation options would be fully credited and would receive the same carbon price. However, there have been policy suggestions to limit the quantity of forest and agriculture based mitigation that can be applied towards meeting the cap (due to concerns about “flooding the market” with these reductions and discouraging emissions reductions in covered sectors) and to apply discounts to carbon reductions to account for leakage and additionality concerns.

As described above, alternative forest and agriculture mitigation activities may fall under either the market for allowances or the market for offsets. In the absence of binding limits, the price per unit of carbon equivalent for allowances and offsets would be expected to equilibrate. However, because domestic legislation under consideration has typically placed limits on the share or quantity of mitigation that can be met using domestic (and international) offsets, the prices of allowances and offsets may diverge. In equilibrium, the allowance price is equal to the marginal cost of abatement for sectors that fall under the cap, while the price of offsets is equal to the marginal cost of providing offsets by sectors that do not fall under the cap to the allowable limit. As the cap is lowered over time, the allowance price tends to increase substantially. However, limitations on offsets as a constant quantity per year or as a percentage of total allowances imply that constant or declining quantities of offsets will be demanded. Thus, the marginal cost of providing those offsets may remain relatively constant over time (e.g., EPA, 2009). In that case, there may be strong incentives to adopt practices that provide GHG mitigation into the allowance rather than the offset market over time.

Methods

We use FASOMGHG to estimate the GHG mitigation potential for U.S. forests and agriculture. This model solves an objective function to maximize discounted net market surplus, represented by the dynamic area under the product demand functions (an aggregate measure of consumer welfare) less the area under factor supply curves (an aggregate measure of producer costs). Such an approach involves solving a nonlinear programming model with endogenous product and factor prices.

The resultant objective function value is consumers' plus producers' surplus. Landowners are assumed to have perfect foresight and base decisions in a given period on the net present value of the future returns to alternative activities. For instance, the decision to continue growing a stand rather than harvesting it now is based on a comparison of the net present value of timber harvest from a future period versus the net present value of harvesting now and replanting (or not replanting and shifting the land to agricultural use). Similarly, landowners make a decision to keep their land in agriculture vs. afforestation based on a comparison of the net present value of returns in agriculture and forestry. Land can also move between cropland and pasture depending on relative returns. This process establishes a land price equilibrium across the sectors (reflecting productivity in alternative uses and land conversion costs) and, given the land base interaction, a link between contemporaneous commodity prices in the two sectors as well.

The model solution portrays simultaneous multi-period, multi-commodity, multi-factor market equilibria, typically over 70 to 100 years on a 5-year time step basis when running the combined agriculture-forest version of the model. The model includes all states in the conterminous U.S., broken into 63 subregions for agricultural production and 11 market regions. Results yield a dynamic simulation of prices, production, management, consumption, GHG effects, and other environmental and economic indicators within these sectors under each scenario defined in the model run.

The key endogenous variables in FASOMGHG include

- commodity and factor prices;
- production, consumption, export and import quantities;

- land use allocations between sectors;
- management strategy adoption;
- resource use;
- economic welfare measures;
- producer and consumer surplus,
- transfer payments,
- net welfare effects; and
- environmental impact indicators:
- GHG emission/absorption of CO_2, CH_4, and N_2O and
- total nitrogen and phosphorous applications.

FASOMGHG quantifies the stocks of CO_2 and non-CO_2 GHGs emitted from, diverted by using bioenergy feedstocks, and sequestered by forestry and agriculture, as well as the CO_2 stock on lands in the model that are converted to developed use. In addition, the model tracks GHG emission reductions in selected other sectors that result from mitigation actions in the forest and agricultural sectors. For instance, the FASOMGHG bioenergy feedstock component accounts for reduced GHG emissions from fossil fuel use in the energy sector due to the supply of renewable bioenergy feedstocks from forestry and agriculture.

Earlier versions of the model have been used for numerous analyses, including a major EPA study of GHG mitigation in the U.S. forestry and agriculture sector (EPA, 2005) as well as other mitigation policy analyses (Lee, 2002; McCarl and Schneider, 2001) and in examining the role of offsets in an economy-wide climate policy.[3] The model has recently undergone substantial enhancements to develop a more detailed representation of the U.S. forestry and agricultural sector. Key improvements include an expanded bioenergy sector that models more than twenty feedstocks used for the production of biodiesel, starch- and sugar-

[3] See Adams et al. (2005) for additional documentation of FASOMGHG and previous model applications.

based ethanol, cellulosic ethanol, and electricity (Beach and McCarl, 2010). Other improvements on the agricultural side include updates to rates of technological change, input costs, and output prices to reflect the current state of the market. In the forestry component of the model, there has been further disaggregation from 10-year to 5-year time steps, and updates to data on timberland stocks, distribution of land ownership, and harvest schedules. Across both agriculture and forest components, the number of GHG categories tracked has been expanded to account for 60 categories of stocks and fluxes in forestry and agriculture. Finally, assumed growth in demand for developed land has been updated to reflect recent projections of income and population growth.

GHG mitigation opportunities in forestry and agriculture include activities such as afforestation (tree planting), forest management (e.g., altering harvest schedules or management inputs), forest preservation, agricultural soil tillage practices, grassland conversion, grazing management, riparian buffers, bioenergy substitutes for fossil fuels, fertilization management, and livestock and manure management. FASOMGHG includes a detailed GHG accounting component, quantifying the stocks of CO_2, CH_4, and N_2O that are sequestered by and emitted from the agriculture and forestry sectors along with the stock of lands that are converted for development. In addition, the model tracks changes in GHG emissions in selected other sectors resulting from forestry and agriculture. For instance, the model accounts for reduced GHG emissions from the fossil fuel use in the energy sector associated with an increase in production of renewable bioenergy feedstocks.

GHG accounting in FASOMGHG accounts for stocks and fluxes in 60 categories, including 18 categories in the forest sector such as CO_2 in forest ecosystem pools, harvested wood products, timber production, and developed land, and 42 categories in the agricultural sector tracking CO_2, CH_4, and N_2O in agricultural ecosystems and feedstocks, crop and bioenergy production, and livestock management.

Table 1 summarizes the major categories of GHG sources and sinks included within FASOMGHG and identifies whether there are opportunities to reduce emissions, sequester carbon, or substitute for fossil fuel use associated with each category as well as the GHGs affected. Sequestration activities can enhance and preserve carbon sinks and include afforestation, forest management, and agricultural soil tillage practices. Agricultural sources of CH_4, N_2O, and fossil fuel CO_2 can be reduced through changes in fertilizer applications and livestock and manure management or alterations in other cropping practices. CO_2 emissions can be reduced by substituting renewable feedstocks for fossil fuels to generate electricity or produce transportation fuels.

For reporting purposes in this paper, the categories are further combined into 7 major categories: forest management, afforestation, agricultural soil carbon sequestration, agricultural CH_4 and N_2O emissions, fossil fuel substitution with bioenergy,[4] fossil fuel use in agricultural production, and carbon sequestration on developed land.

In addition to quantifying GHG emissions and sinks, FASOMGHG distinguishes the unique time dynamics and accounting issues of carbon sequestration options. These include non-permanence issues such as saturation (or equilibrium level) of carbon sequestration over time, potential reversibility of carbon benefits, and fate of carbon stored in products after forest harvest. These can be compared with options for agricultural non-CO_2, fossil fuel CO_2, and bioenergy that do not exhibit saturation or reversibility and are permanent reductions.

[4] These reductions represent the net emissions saved from substituting feedstocks for fossil fuels in the transportation and electric power sectors after accounting for GHGs emitted while processing and transporting the biomass.

Table 1. Major Categories of GHG Sources and Sinks in FASOMGHG

Source/Sink	Category of Potential Mitigation	CO_2	CH_4	N_2O
Forestry				
Afforestation	Sequestration	X		
Reforestation	Sequestration	X		
Timberland management	Sequestration	X		
Harvested wood products	Sequestration	X		
Agriculture				
Manure management	Emission		X	X
Crop mix alteration	Emission, Sequestration	X		X
Crop fertilization alter.	Emission, Sequestration	X		X
Crop input alteration	Emission	X		X
Crop tillage alteration	Emission, Sequestration	X		X
Grassland conversion	Sequestration	X		
Irrigated/dryland mix	Emission	X		X
Rice acreage	Emission	X	X	X
Enteric fermentation	Emission		X	
Livestock herd size	Emission		X	X
Livestock system change	Emission		X	X
Bioenergy				
Conventional ethanol	Fossil Fuel Substitution	X	X	X
Cellulosic ethanol	Fossil Fuel Substitution	X	X	X
Biodiesel	Fossil Fuel Substitution	X	X	X
Bioelectricity	Fossil Fuel Substitution	X	X	X
Development				
Carbon on developed land	Sequestration	X		

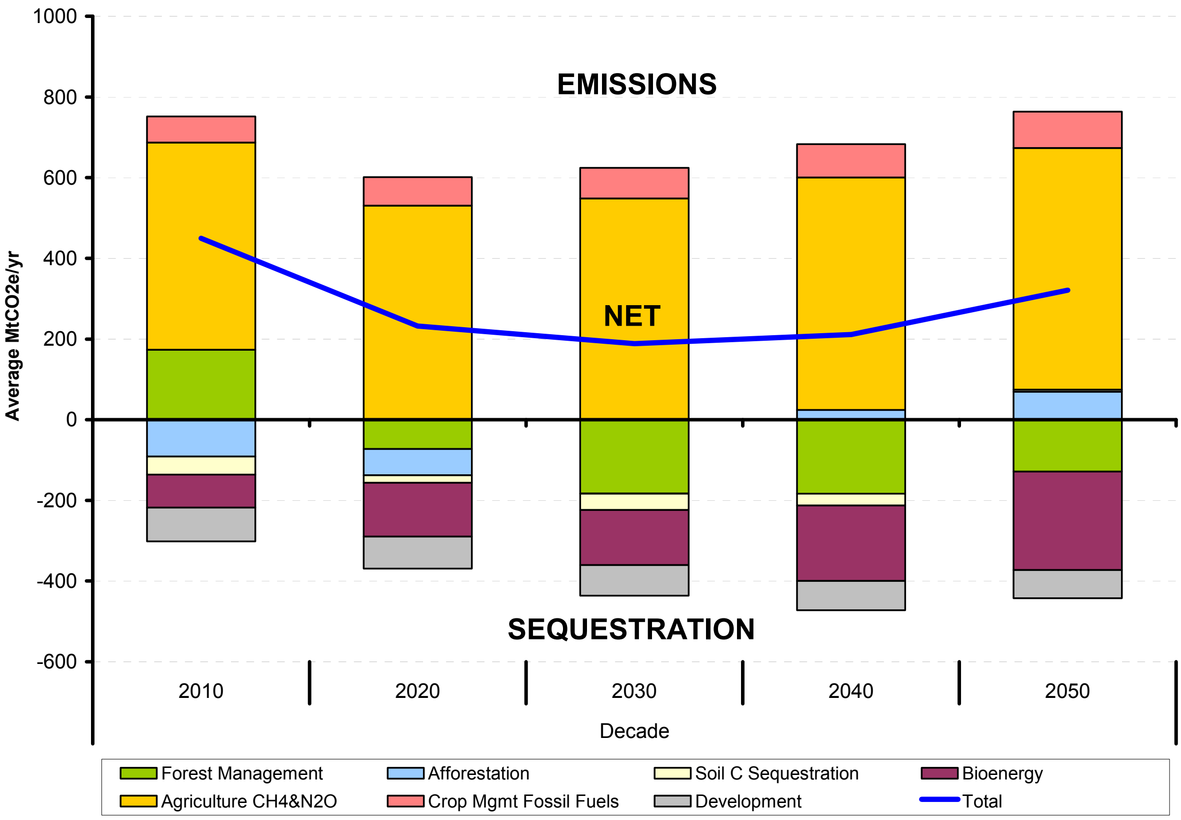
Model Baseline and Policy Scenarios[5]

Under the updated renewable fuel standards (RFS2) promulgated in 2010 to meet the requirements of the Energy Independence and Security Act of 2007 (EISA), the use of biomass feedstocks is expected to increase over time as production of renewable biofuels is required to reach 36 billion gallons per year by 2022. Of that total requirement, we assumed for this analysis that 30 billion gallons per year would be derived from U.S. forestry and agricultural feedstocks by 2022, with the remainder coming primarily from municipal waste and imports. The majority of the increment above baseline renewable fuels production is expected to come from cellulosic ethanol in order to meet the advanced biofuels volume component of RFS2 specified volume requirements.[6]

Baseline GHG estimates with EISA requirements met, but without a carbon price, are shown in Figure 1. This baseline differs from previous applications of the model (EPA, 2005), which generated estimates that were consistently greater than or equal to net emissions in the updated model. Differences in the projected emissions can be attributed to changes in global GDP growth, population, consumer preferences (e.g., greater demand for meat), technological change, tillage practices, and an increase in the mandate for renewable fuels, among other things. Apparent in the figure is that fluxes from agriculture are relatively consistent, with non-CO_2 gases contributing a majority of the emissions. Additionally, because there is a strong demand for agricultural commodities and biomass feedstocks in the early periods, private timberland is estimated to be a source of emissions in 2010 before reverting back to its conventional role as a net sink. Baseline biomass use in bioenergy production increases over time as cellulosic ethanol production increases due to EISA volume requirements.

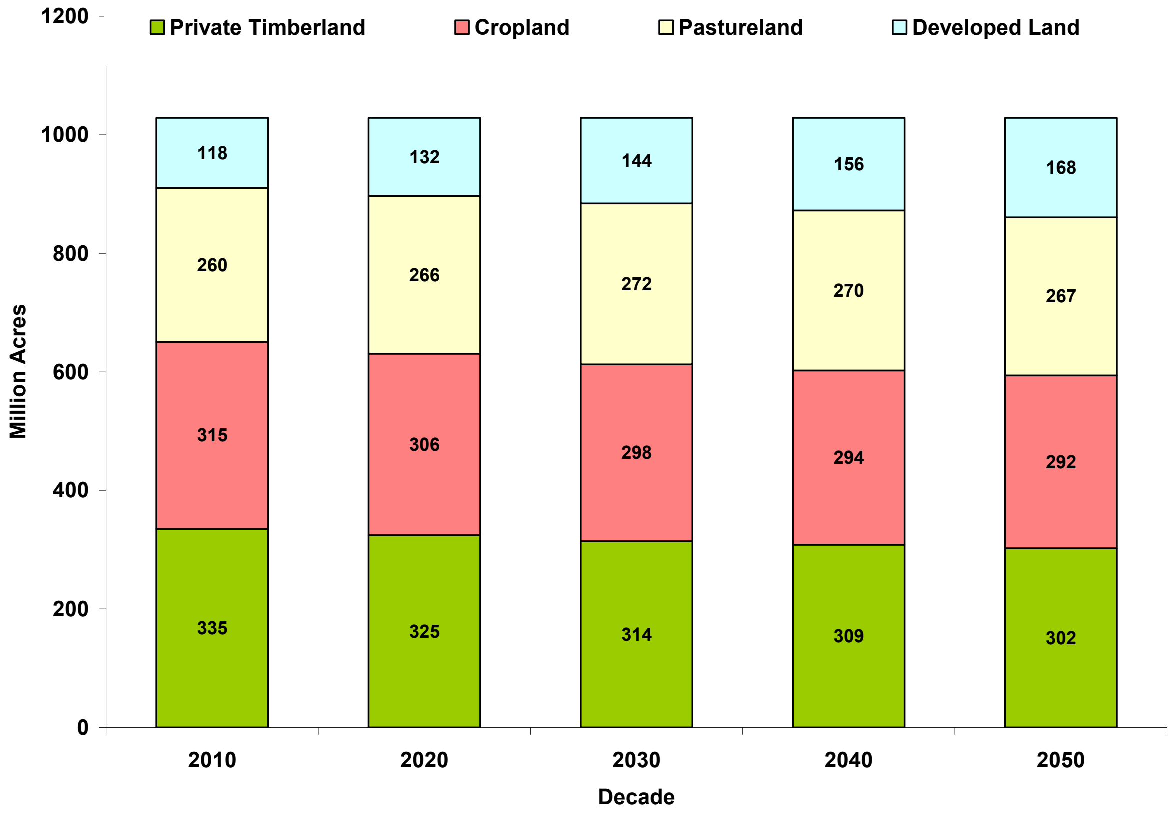
[5] As noted previously, results presented in this paper are preliminary. Model development and analysis is ongoing and the baseline and policy scenario results are subject to change as additional model updates and analyses are completed.
[6] EISA limits conventional ethanol (primarily produced using corn in the U.S.) to providing a maximum of 15 billion gallons per year towards meeting the total volume requirements, which is reflected in RFS2 volumes.

Figure 1. FASOMGHG Baseline GHG Emissions (MtCO2e/yr)



FASOMGHG baseline private land use for the conterminous U.S. is presented in Figure 2, and shows that private timberland and cropland diminish as land is converted for developed uses while pastureland remains relatively constant. The area of developed land increases over time due to increases in population and income, leading to ongoing reductions in total land available for forests and agricultural. In the baseline, private timberland and cropland tend to decline over time while pasture area increases due to increasing crop productivity over time (reducing the land area required to meet consumer demand) in combination with increased demand for livestock products.

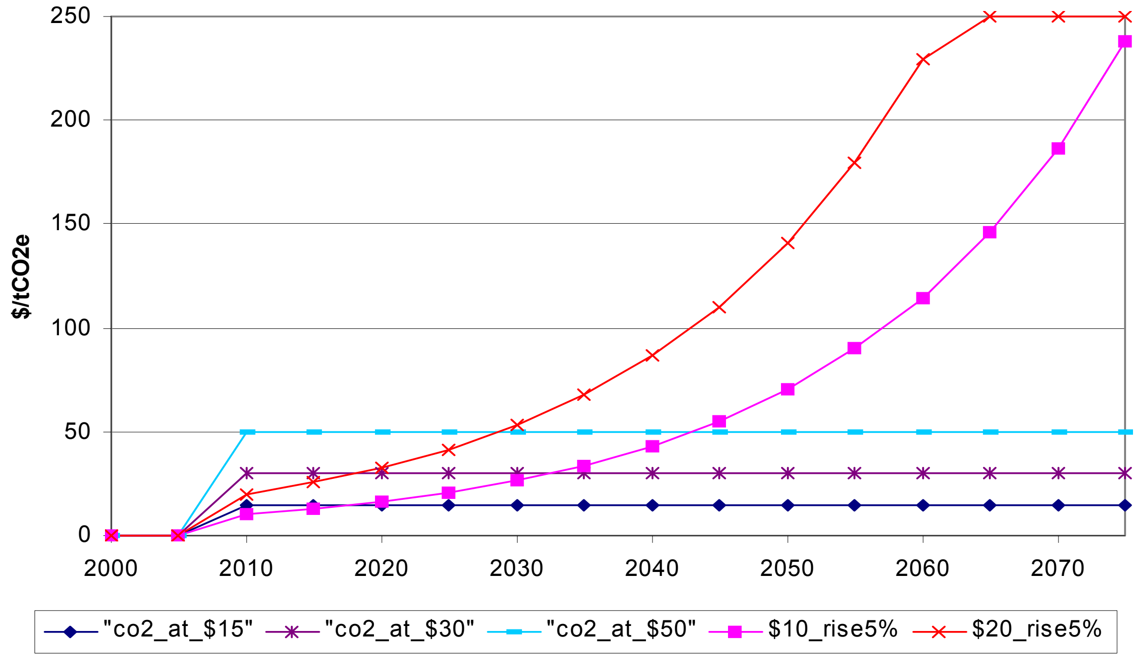
Figure 2. FASOMGHG Baseline Land Use (Million Acres)



For our examination of the potential of different mitigation practices and their role in markets, we apply the model to simulate equilibrium outcomes over the next century under a wide range of alternative CO_2e prices for allowances and offsets. Mitigation potential is reported as changes from baseline trends, starting in 2010 and projected out 50 years in five year time steps. The first set of scenarios assumes that GHG prices remain constant for the duration of the policy at prices ranging from \$15 to \$50 per metric ton CO_2e. The second group of scenarios assumes that GHG prices will rise over time until they reach an exogenous price cap. The dynamic price path of these policies is outlined in Figure 3.[7] The rising price scenarios provide insight on the potential changes in landowner behavior and a delay of action that could occur in this forward looking model. We also investigate mitigation potential and agriculture and forest sector impacts when using a combination of rising allowance prices and constant offset prices.

[7] We focus on representative results from selected runs in this paper.

Figure 3. Carbon Prices over Time under Alternative Scenarios



In addition, we examined a variety of policy options that vary the eligibility of alternative mitigation practices for carbon payments to estimate changes in total mitigation and mix of options adopted. Under our full eligibility scenarios, all domestic mitigation opportunities included in the model are eligible for carbon payments based on the full value of their reduction in GHG. In the combination price scenarios, a rising GHG price is applied to bioenergy and agricultural fossil fuel combustion emissions, while a constant price is applied to all other activities.

It is also possible that some practices would not be eligible for carbon payments due to difficulties with such things as measurement and monitoring, leakage, or other implementation issues. Our limited eligibility scenarios assume that only afforestation and manure management are eligible offsets, though carbon prices also apply for mitigation options available to sectors likely included under a greenhouse gas cap in that they are related to the substitution or reduction of fossil fuel combustion. Specifically, these options include bioenergy production and fossil fuel use in agricultural production. Another option for addressing the uncertainties regarding net GHG mitigation for specific practices is to discount the carbon credits associated with those practices. Under our discounted eligibility scenarios, all options receive carbon payments, but those excluded from the limited eligibility scenarios receive discounted payments of only 50% of the carbon price that those options included under the limited eligibility scenarios receive. In addition, we explored additional scenarios where either forest or agricultural emissions were excluded or discounted or both. Across all of these eligibility scenarios, we present results for constant carbon prices of \$15, \$30, and \$50/tCO_2e from 2010 to 2050.

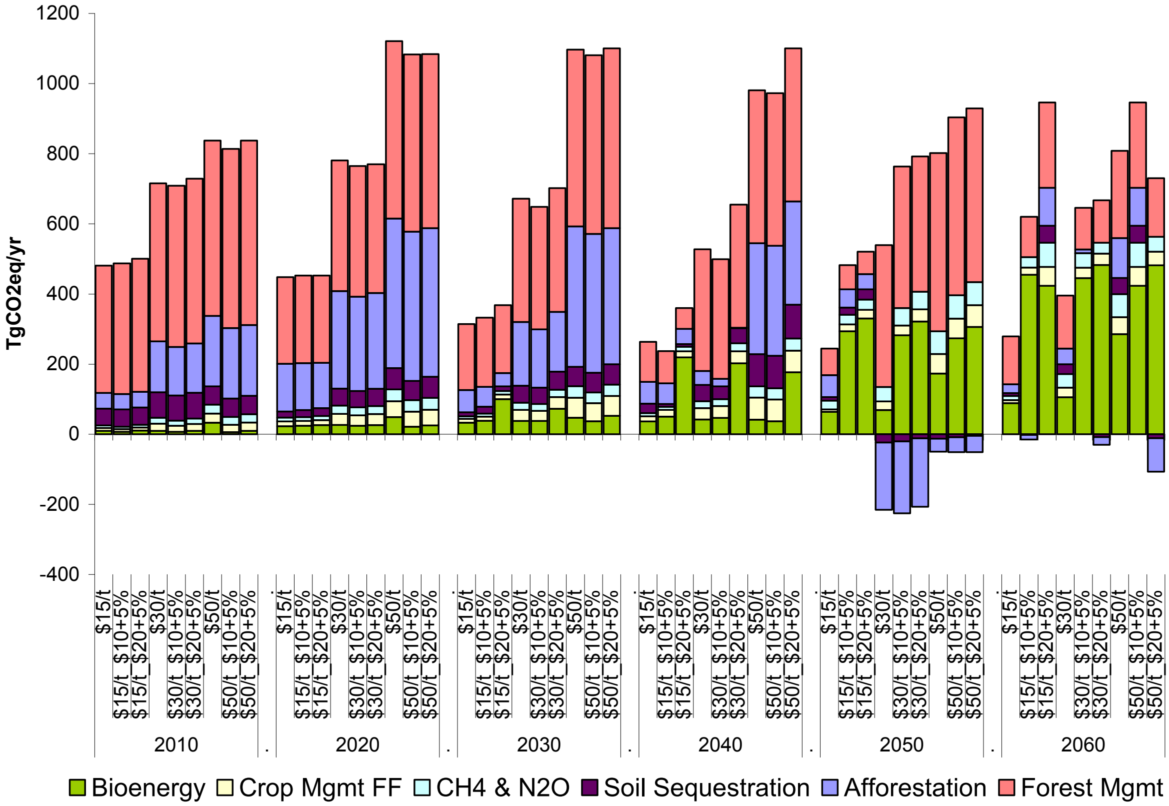
Results

As described above, the carbon policy scenarios modeled assumed various combinations of offset and allowance carbon as well as a variety of different combinations of mitigation option eligibility for the forestry and agricultural sectors.[8]

Figure 4 shows simulated GHG mitigation potential for several different carbon price paths and combinations of allowance and offset prices. At a carbon price of \$50/tCO_2e, mitigation potential averages almost 1000 Mt CO_2e/year. There is relatively little difference between the scenarios with differing prices in the allowance and offset markets in early years, but both total mitigation and the mix of mitigation options become increasingly divergent over time as the gap between the carbon prices in the two markets increases. As expected, the mitigation reductions associated with provision of feedstocks for bioenergy are larger when the allowance price is rising over time relative to the offset price. Afforestation provides large quantities of mitigation in early years, but provides a smaller sink or a source in later decades as the afforested lands are harvested. Although reductions in fossil fuel use in the agricultural sector are also credited at the allowance price, there is relatively little responsiveness in fossil fuel use.

[8] Current results presented in this paper are preliminary. Model development and analysis is ongoing and the results are subject to change as additional model updates and analyses are completed

Figure 4. FASOMGHG GHG Mitigation Potential with Different Combinations of Carbon Price Paths (MtCO2e/yr), 2010-2060



Note: \$15/t, \$30/t, and \$50/t denote constant carbon prices at those levels applied to both allowance and offset markets. The rest of the labels denote combinations of constant offset prices and rising allowance prices in the format "constant offset price_2010 allowance price+annual increase in allowance price until reaching cap", e.g., \$15/t_\$10+5% indicates that allowances receive a constant price of \$15/tCO_2e whereas allowances are priced at \$10 in 2010 and increase at a rate of 5% per year afterwards until reaching a maximum of \$250/ tCO_2e.

As shown in Figure 5, the proportion of forestry and agricultural mitigation attributable to mitigation options that are in the allowance market increases over time even at a constant carbon price as improvements in crop yields and feedstock to ethanol conversion yields make bioenergy a more attractive mitigation option over time. In cases with rising allowance prices, the majority of forestry and agricultural mitigation is taking place with options that fall under the allowance market by 2050 and they account for 74-84% of mitigation potential by 2060. In large part, this is due to the fact that it is economical to harvest timber around 2050 and new forest growth, and the associated sequestered carbon included in the offset market, accumulates gradually in subsequent years.

Figure 5. Proportion of Forestry and Agricultural Mitigation for Capped Emissions, \$30/tCO2e Offset Price

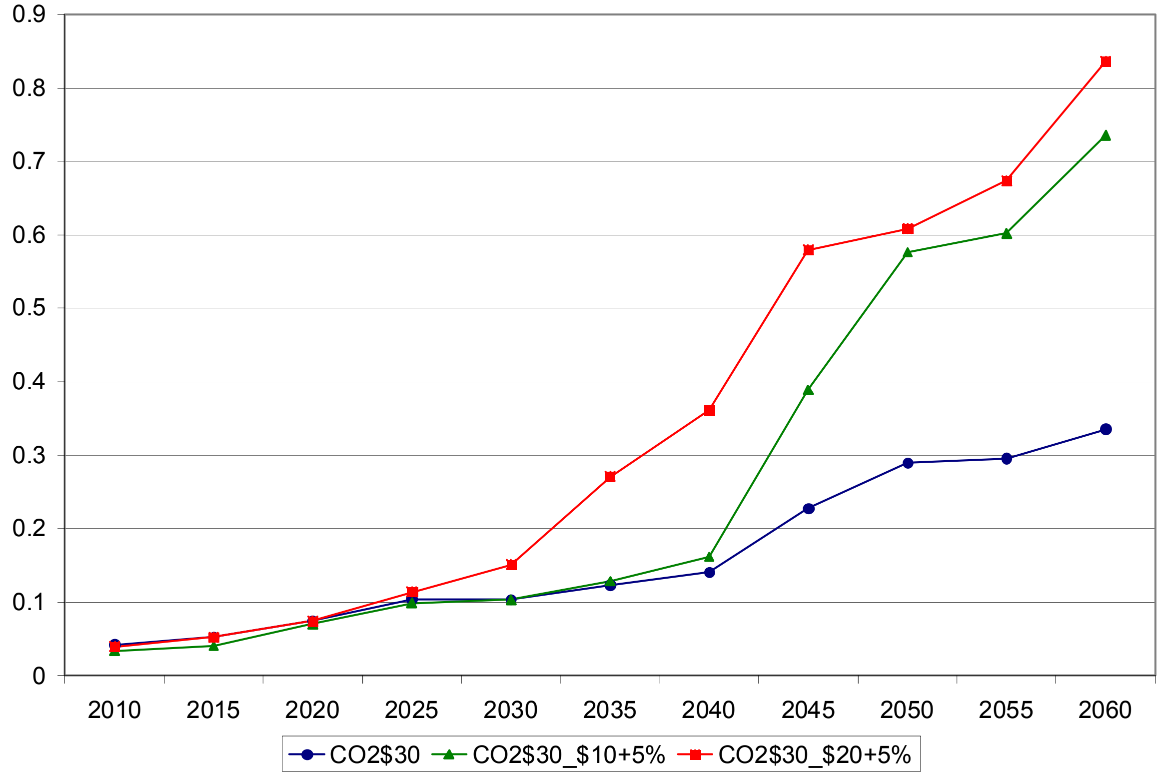


Figure 6 shows the relative amount of total mitigation simulated as well as mitigation coming from options providing allowances and from those providing offsets when allowance prices are rising relative to a case where allowance and offset prices are both constant at \$30/tCO_2e. Total mitigation increases by more than 50 percent in later years when allowance prices are rising, with mitigation from those practices competing in the allowance market rising to about four times as high as with a constant price and mitigation from practices providing offsets falling to less than half their levels with a constant allowance price by 2060. This reflects shifts in land use and mitigation options chosen as relative prices change.

Having separate prices for allowances and offsets seems to have relatively little effect on land use change over the next few decades, but begins to induce decreases in private timberland and pasture relative to cropland starting around 2040 (see Figure 7). Increased bioenergy production increases the relative returns to cropland relative to other uses, although there is still net movement of land into timberland in all years and all cases.

Figure 6. Mitigation from Combination Price Scenarios Relative to Constant Price of $30/tCO2e

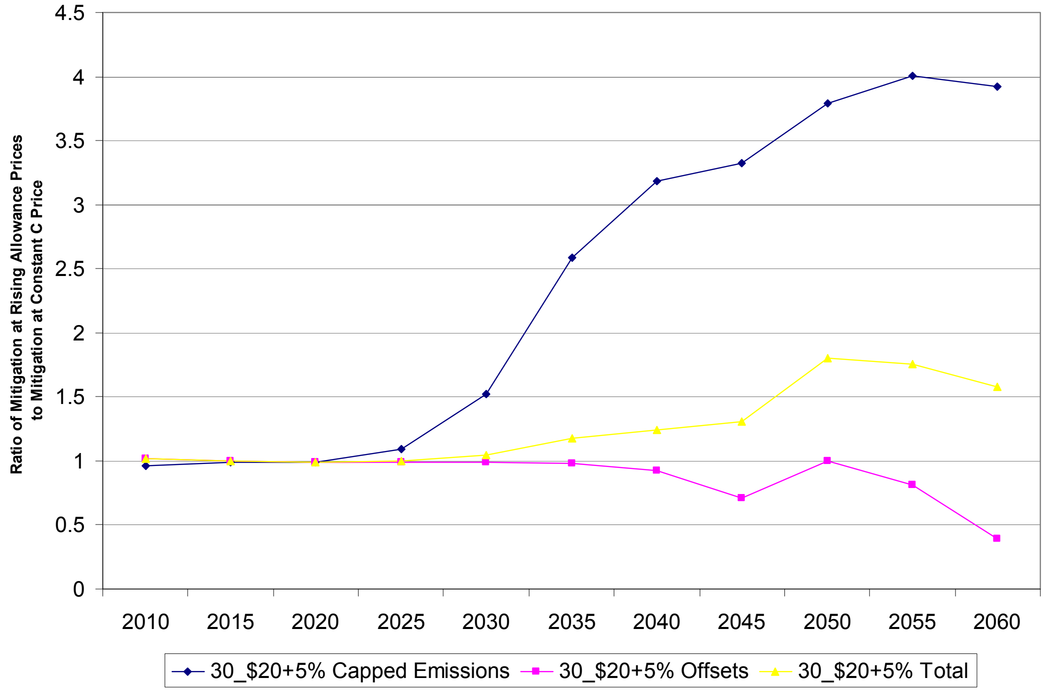


Figure 7. Percentage Land Use Change Relative to Baseline, Offset Price of $30/tCO2e

In addition to modeling effects of differing allowance and offset prices on GHG mitigation, we modeled a number of different scenarios for mitigation option eligibility for carbon payments. Under the full eligibility scenario, the forest and agricultural sectors can potentially provide 200 to 1000 Mt CO_2e of mitigation annually for constant prices of \$15 to 50/tCO_2e, as shown in Figure 8. The majority of GHG mitigation provided by these sectors is from forest management and afforestation. There is some mitigation from bioenergy production, but it is small. This is largely due to the volume of biofuels entering in the baseline, which limits mitigation potential.

Figure 8. GHG Mitigation Potential with Full Eligibility of Mitigation Options at Different Carbon Prices

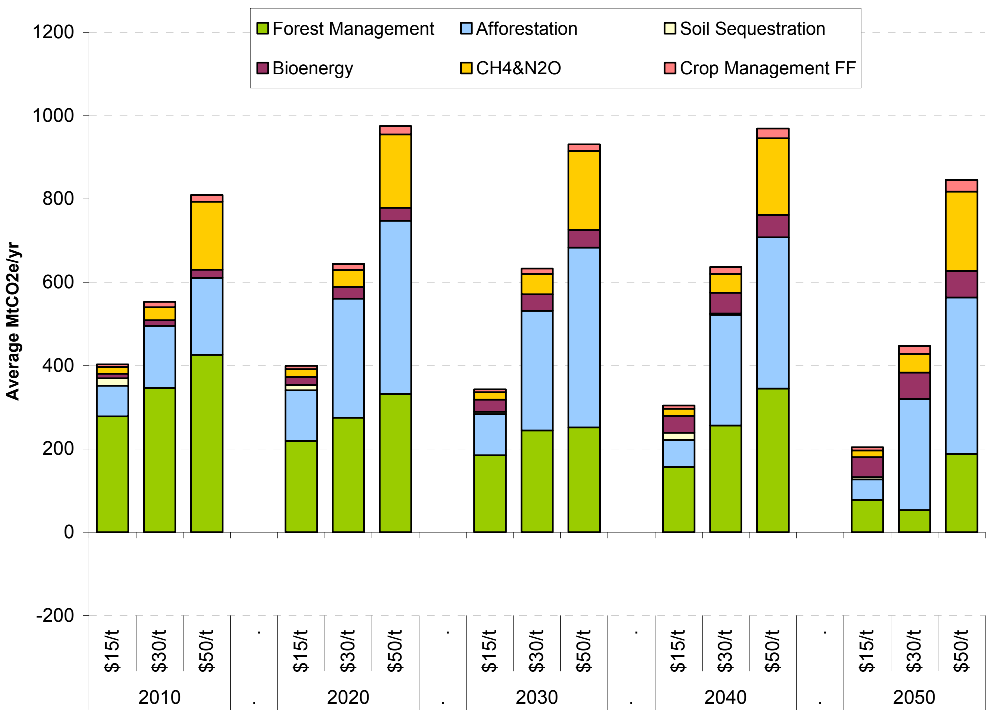
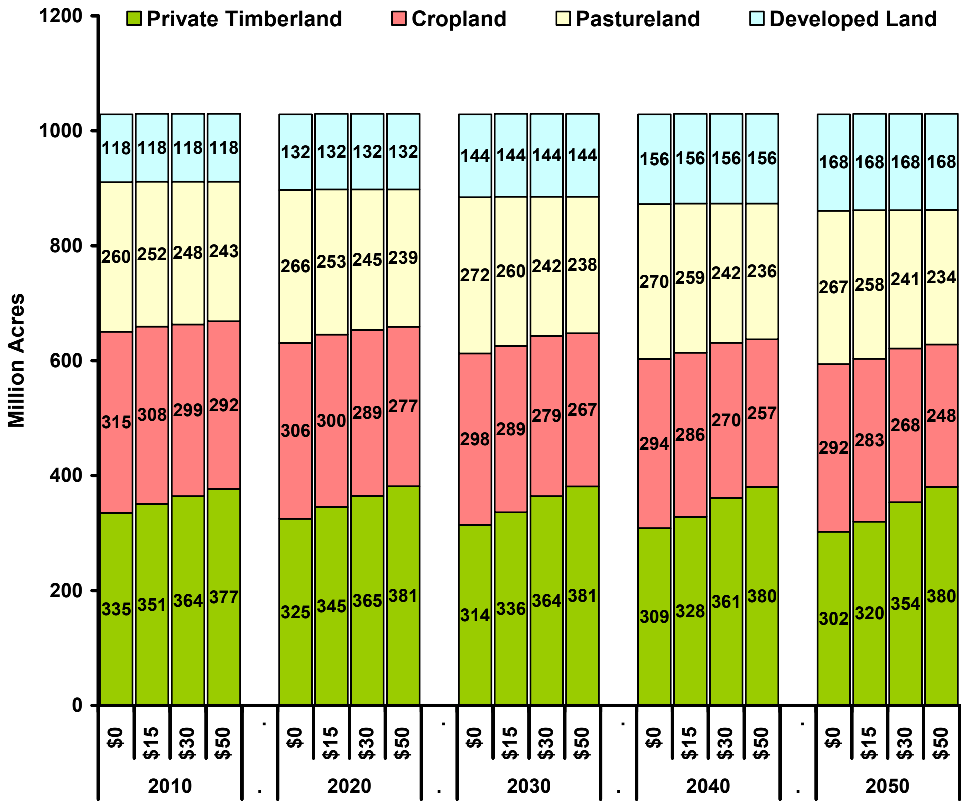


Figure 9 shows land use at alternative carbon prices under the full eligibility scenarios. Carbon prices results in major land reallocation from agriculture to forests. By 2050, private timberland area is 26 percent larger with a carbon price of \$50/tCO_2e than in the baseline, while cropland and pasture areas are reduced by 15 percent and 12 percent, respectively.

Figure 9. Land Use with Full Eligibility of Mitigation Options at Different Carbon Prices



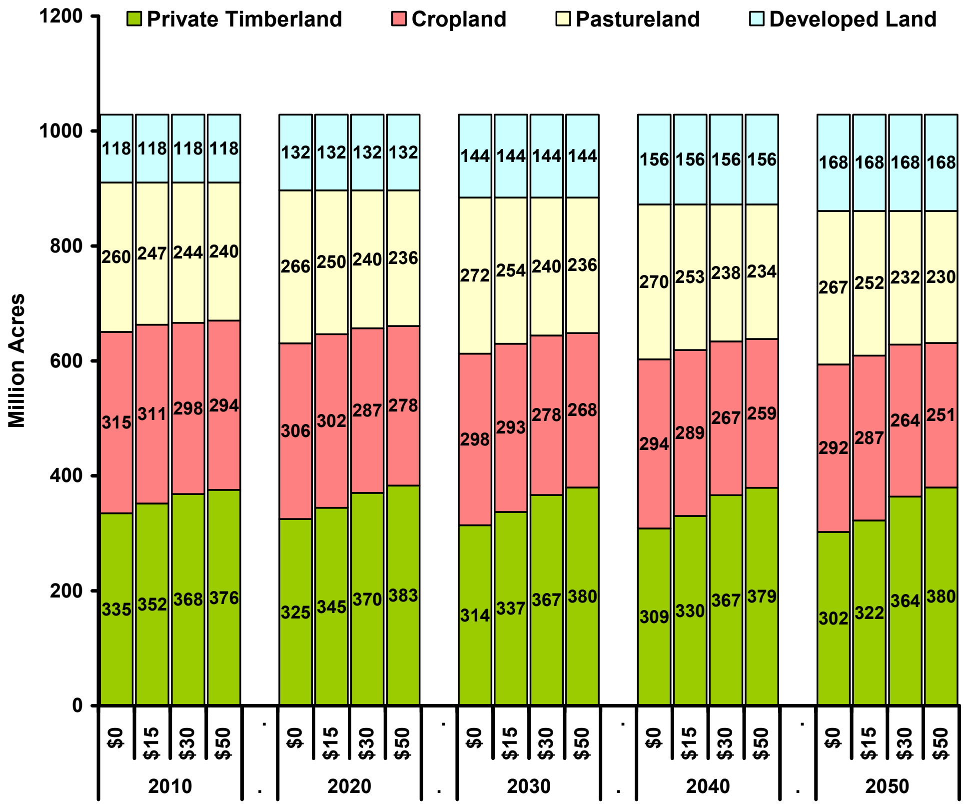
For the limited eligibility options, total net mitigation available at $50/t$CO_2$e declines to an average of about 600 Mt/year (see Figure 10). In addition, the majority of emissions reductions are now derived from afforestation and manure management (the two eligible offset categories in these scenarios), as expected. Forest management goes from being a large sink under full eligibility to a source as there are now incentives to convert existing forests to cropland and pasture and afforest existing agricultural lands.

Figure 10. GHG Mitigation Potential with Limited Eligibility of Mitigation Options

Note: Under the limited eligibility scenario, only afforestation and manure management are eligible offsets. Options that would fall under capped sectors (bioenergy production and fossil fuel use in agricultural production) also receive carbon payments.

As shown in Figure 11, land use under the limited eligibility options is much more similar to the full eligibility scenario than for GHG mitigation. There is a slightly larger increase in private timberland and smaller decrease for cropland while pasture area declines more than the full eligibility case.

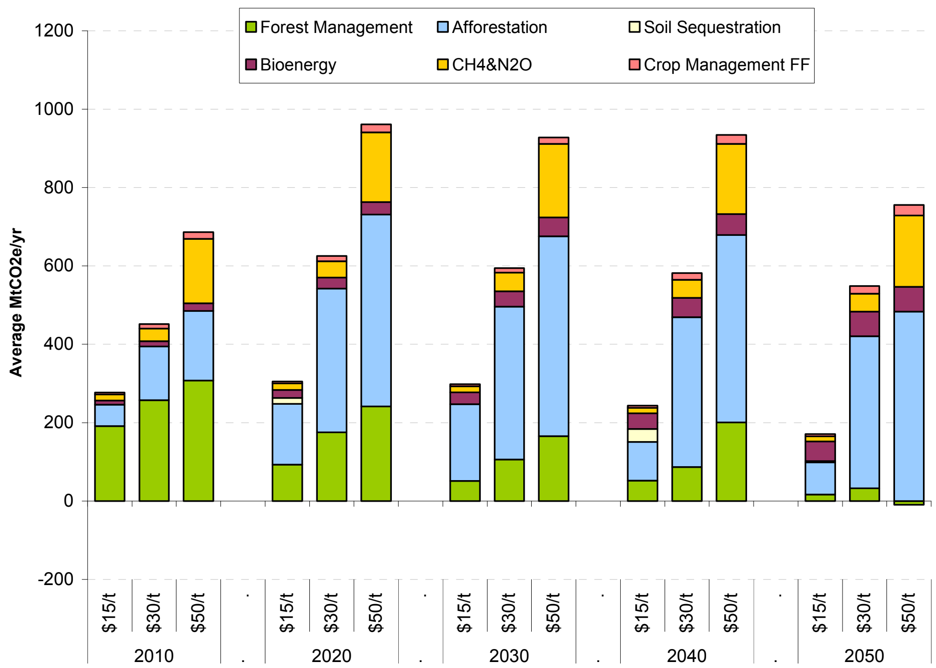
Figure 11. Land Use with Limited Eligibility of Mitigation Options



As expected, the results of the discounted eligibility scenarios generally fall between the full and limited eligibility cases. Net GHG mitigation now averages around 800 Mt/year at \$50/tCO_2e (see Figure 12). The mix of mitigation options is similar to the full eligibility case, but with less mitigation from forest management. Although forest management is an important mitigation option under discounted eligibility, its magnitude is clearly reduced relative to the full eligibility case because landowner incentives for modifying their forest management have been reduced.

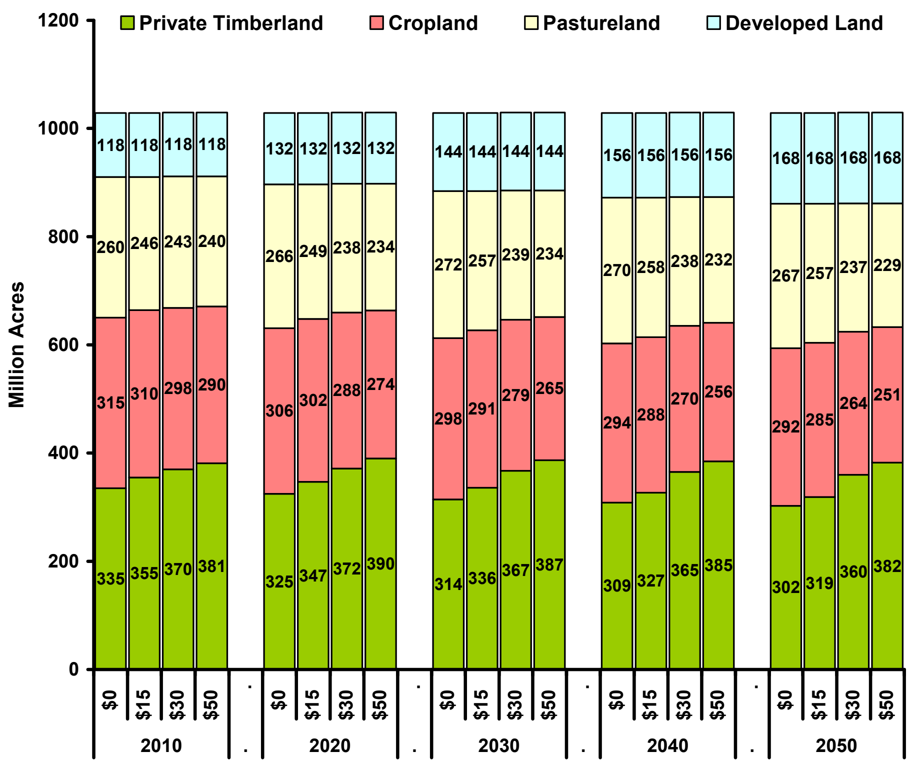
As shown in Figure 13, land use under the discounted eligibility options is similar to the previous two scenarios, but there are additional reductions in pasture relative to cropland under this set of model results.

Figure 12. GHG Mitigation Potential with Discounted Eligibility of Mitigation Options



Note: Under the discounted eligibility scenario, only afforestation and manure management are offsets credited at the full carbon price. Other offsets are credited at 50% of the full carbon price. Options that would fall under capped sectors (bioenergy production and fossil fuel use in agricultural production) also receive full carbon payments.

Figure 13. Land Use with Discounted Eligibility of Mitigation Options



Figures 14 and 15 present annualized equivalent estimates of net GHG mitigation between 2010-2050 (using a discount rate of 4 percent) for scenarios with limited and discounted mitigation options, respectively, and comparing cases where either forestry mitigation options, agricultural mitigation options, both, or neither are excluded or discounted. Forestry options provide the majority of the mitigation from these sectors in all cases where they are included.

Limited eligibility across both forest and agricultural options reduces total annualized mitigation by 38 to 62 percent, whereas excluding all forestry offsets but including all agricultural offsets reduces mitigation potential by an even larger amount of 77 to 90 percent. Excluding only agricultural offsets while including forestry offsets, on the other hand, results in a range of net GHG changes between a 7 percent increase in mitigation and a 9 percent decrease across carbon prices considered. For the discounted eligibility results, mitigation potential remains relatively high with the largest reductions in mitigation potential occurring when forestry offsets are discounted and agricultural offsets are not. That case results in a 37 to 44 percent reduction in mitigation potential, as shown in Figure 15.

Figure 14. Annualized Mitigation Potential with Limited Eligibility, 2010-2040

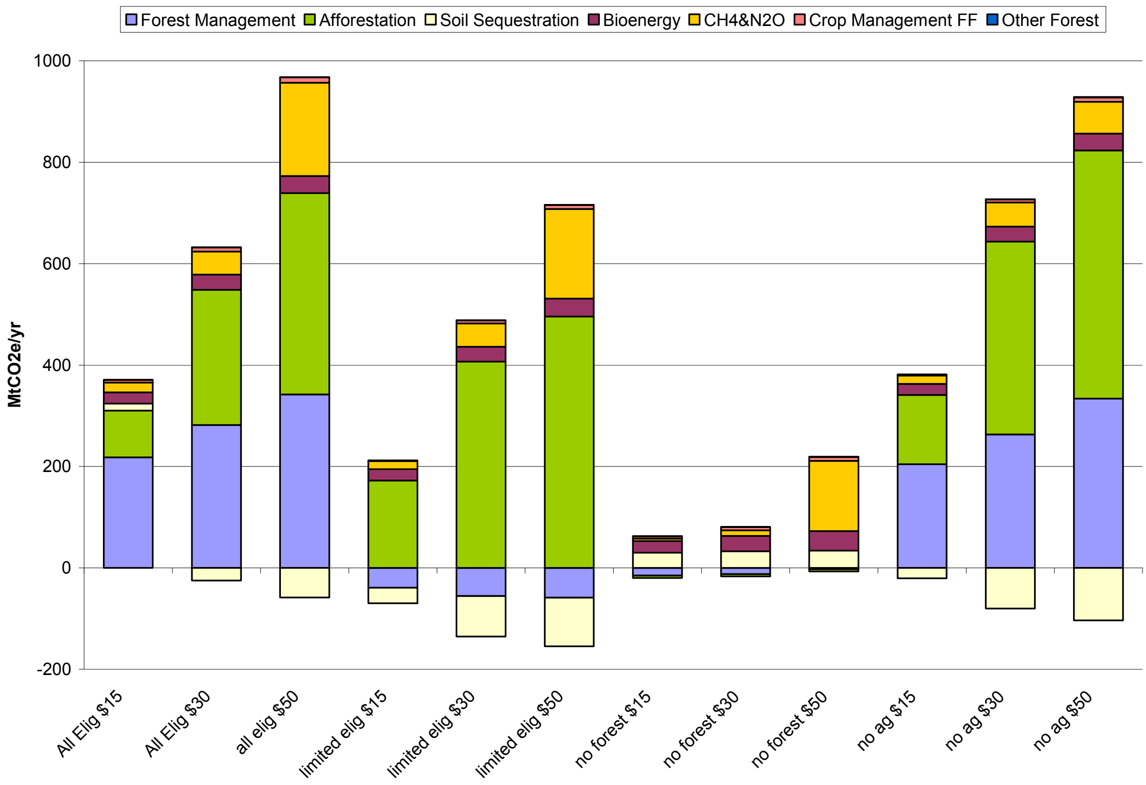
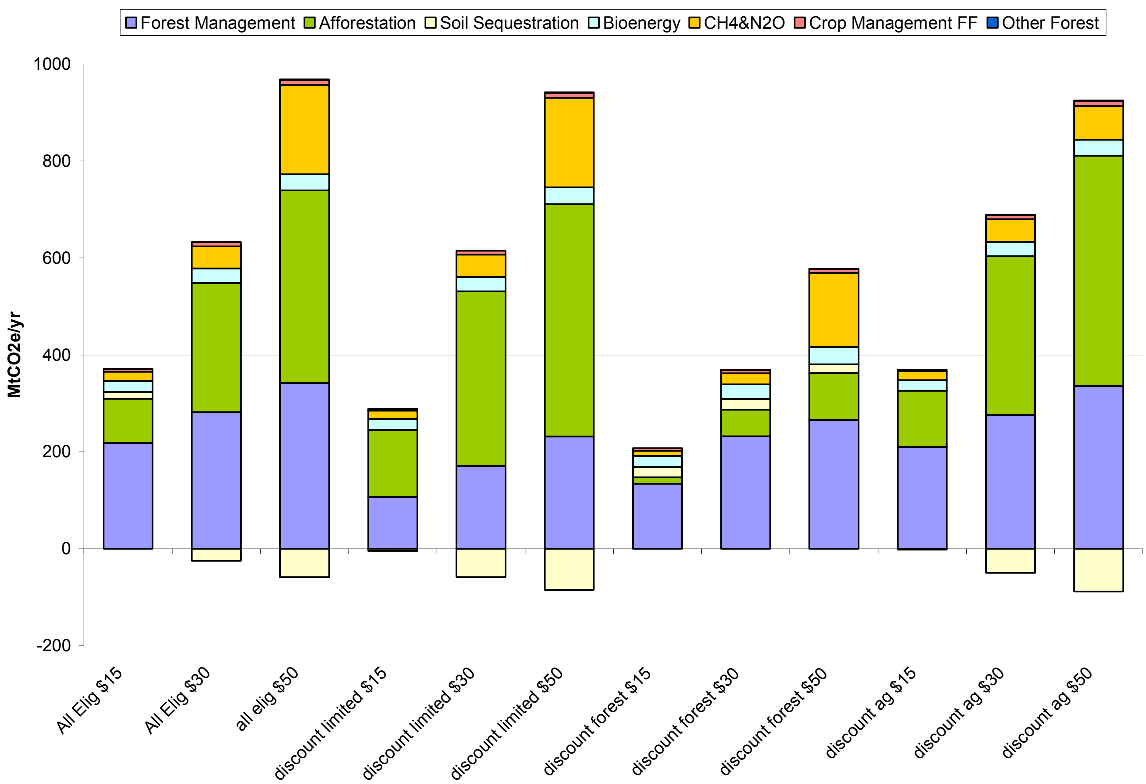


Figure 15. Annualized Mitigation Potential with Discounted Eligibility, 2010-2040



Conclusions

There has been growing interest in climate policy in recent years and the mitigation role forestry and agricultural sectors can play in containing costs and providing opportunities for more stringent climate management. In this study, we apply one of the most comprehensive U.S. forestry, agriculture, and land use models available to explore the implications of alternative GHG mitigation policy design. Our preliminary results suggest that forestry and agriculture could provide mitigation of 200 – 1000 Mt CO2e/year at prices of $15 to $50/tCO2e. However, constraining opportunities for reducing emissions by limiting sources, regions, or practices eligible for offsets or placing a cap on offsets will increase total costs of hitting a given mitigation target. We also show that differences in relative prices for allowances (which are applied to mitigation from bioenergy and agricultural fossil fuel use in this study) and offsets could substantially affect the distribution of mitigation across options as well as total mitigation potential at a given carbon price. Although the EISA requirements for 36 billion gallons of renewable fuels by 2022 increased baseline bioenergy production in FASOMGHG and reduced mitigation potential for bioenergy relative to that higher baseline level of use, increasing prices for allowances relative to offsets over time could nonetheless lead to an increasingly large role for bioenergy in the mitigation portfolio in future decades.

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